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## TRANSMITTAL OF APPEAL BRIEF (Large Entity)

Docket No.  
FIS920000396US1

In Re Application Of: Mukesh V. Kharc, et al.

Serial No.  
09/809,663Filing Date  
3/15/01Examiner  
Fernando L. ToledoGroup Art Unit  
2823

Invention: METHOD FOR IMPROVED PLASMA NITRIDATION OF ULTRA THIN GATE DIELECTRICS

TO THE COMMISSIONER FOR PATENTS:

Transmitted herewith in triplicate is the Appeal Brief in this application, with respect to the Notice of Appeal filed on

The fee for filing this Appeal Brief is: \$330.00

- ☐ A check in the amount of the fee is enclosed.
- ☒ The Director has already been authorized to charge fees in this application to a Deposit Account.
- ☒ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. 09-0458 (FI-039)

Margaret A. Pepper  
Signature

Dated: February 12, 2004

MARGARET A. PEPPER  
REG. NO.: 45,008  
ATTORNEY FOR APPLICANT

I certify that this document and fee is being deposited on  
February 12, 2004 with the U.S. Postal Service as first  
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22313-1450.

Karen Cinq-Mars 2/12/04  
Signature of Person Mailing Correspondence

KAREN CINQ-MARS

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Karen Cinq-Mars

Name of Person Mailing Paper and Fee

*Karen Cinq-Mars 2/12/04*  
Signature of Person Mailing Paper and Fee

## In the United States Patent and Trademark Office

**Date:** February 12, 2004

**In re Application**  
**of:** Mukesh V. Khare et al.

**Filed:** March 15, 2001

**For:** METHOD FOR IMPROVED PLASMA NITRIDATION OF  
ULTRA THIN GATE DIELECTRICS

**Serial Number:** 09/809,663

**Art Unit:** 2823

**Examiner:** Fernando L.  
Toledo

### BRIEF FOR APPELLANTS UNDER 37 C.F.R. § 1.192

#### **Mail Stop: Appeal Brief - Patents**

Hon. Commissioner of Patents and Trademarks  
P.O. Box 1450  
Alexandria, VA 22313-1450

Sir:

This is an appeal from the final Office Action mailed September 17, 2003, rejecting Claims 1-3 and 6-8. A Notice of Appeal and the required fee were timely filed on December 17, 2003. Three copies of this Appeal Brief are enclosed.

09/809,663

FIS920000396US1

***Real Party in Interest***

The real party in interest is the assignee of the entire right, title and interest in this application, International Business Machines Corporation, a corporation of the State of New York, having a place of business at Armonk, New York 10504.

***Related Appeals and Interferences***

There are no appeals or interferences known to Appellants, Appellants' legal representatives, or assignee, which will directly affect or be affected by or have a bearing on the Board's decision in the pending appeal.

***Status of Claims***

The subject application was filed on March 15, 2001 with Claims 1-13. In a first Office Action mailed February 28, 2002, Claims 9-13 were withdrawn from consideration and Claims 1-8 were rejected. An Amendment was filed on May 28, 2002, canceling Claims 4, 5 and 9-13 and amending Claims 1-3. A second Office Action mailed August 8, 2002 was made final, and the prior art rejections of Claims 1-3 and 6-8 were maintained. A response was filed on October 8, 2002, presenting arguments and a declaration under 37 C.F.R. 1.132. In a third Office Action mailed November 11, 2002, the finality of the previous Office Action was withdrawn, the prior art rejections of Claims 1-3 and 6-8 were also withdrawn, and these claims were rejected only under the nonstatutory doctrine of obviousness-type double patenting. A response was filed on December 30, 2002, which included a terminal disclaimer to overcome the double patenting rejection.

Instead of a Notice of Allowance, a fourth Office Action was mailed March 20, 2003, essentially repeating the same rejections which appeared in the second Office Action mailed August 8, 2002. In an Amendment filed June 20, 2003, arguments were re-presented, again referring to the declaration under 37 C.F.R. 1.132, and Claim

1 was amended. A final Office Action followed on September 17, 2003, maintaining the rejection of Claims 1-3 and 6-8. Appellants are appealing the rejection of these claims.

Appellants also wish to note that a Supplemental Information Disclosure Statement (IDS) was filed on July 8, 2003. This Supplemental IDS was filed before the mailing date of the final Office Action and was accompanied by a statement that each item of information contained in the IDS was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the IDS. Even though the requirements of 37 C.F.R. 1.97(c) have been satisfied, receipt of this Supplemental IDS has not been acknowledged, and this Supplemental IDS has not been made of record in the application.

#### ***Status of Amendments***

All the amendments made during prosecution of the application have been entered. The rejected Claims 1-3 and 6-8, as they presently stand, are set forth in Appendix A. No amendment has been filed subsequent to the final rejection.

#### ***Summary of Invention***

The present invention is directed to a method for improved plasma nitridation of ultra thin gate dielectrics in integrated circuits. Specifically, this method addresses the need for a method which results in a higher nitrogen concentration or dosage in the dielectric, yet does not substantially increase the dielectric thickness or sacrifice the uniformity of film thickness.

Prior to the present invention, it was known that nitrogen doping of silicon oxide dielectric material, particularly by Remote Plasma Nitridation (RPN), increases the dielectric constant of the material. An increased dielectric constant in gate dielectrics is desirable to help reduce the amount of leakage current experienced as compared to an undoped silicon oxide layer having the same capacitance.

Conventional methods of plasma nitridation, however, have several drawbacks when used in conjunction with gate thicknesses of around 15 Å or less. First, a relatively strong concentration of nitrogen ( $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> or greater) introduced into an oxide layer by RPN, while desirable for the purpose of reducing leakage current, causes an additional growth of the layer. In ULSI integrated circuits, it is desired to maintain the physical thickness of gate dielectrics to around 15 Å. An oxide gate dielectric layer having an initial physical thickness of approximately 15 Å, when subjected to RPN, will grow in physical thickness by as much as 10-15 Å. This additional growth caused by conventional plasma nitridation is therefore highly undesirable in ULSI integrated circuits. Secondly, the direct nitridation of a silicon oxide layer typically results in a non-uniform distribution of nitrogen atoms within the layer. As a result, the uneven growth of film at the interface during nitridation affects the overall uniformity of the film thickness.

These deficiencies of the prior art are overcome by the method of the present invention. The method comprises the steps of: forming an initial oxynitride layer upon a substrate material, and subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer. It is a feature of the present invention that the final oxynitride layer has both an equivalent oxide thickness of less than 15 Å and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. The equivalent oxide thickness is a relative measure of gate dielectric thickness with respect to the actual thickness of a silicon oxide layer having the same capacitance value as the given gate dielectric. Applicants have surprisingly discovered that when the initial layer is a heavily nitrided oxynitride layer instead of a silicon oxide layer, a final oxynitride layer is produced which has a substantially decreased thickness without compromising the high nitrogen concentration in the dielectric.

It is an additional feature of the present invention that the final oxynitride layer further has a reduction in effective electron mobility of less than 20% from the effective electron mobility of the initial oxynitride layer. Electron mobility relates to the

speed of the device. A conventional method involving plasma nitridation of a silicon oxide film can cause the effective electron mobility of the gate dielectric to be reduced by as much as 50-70 %. In gate dielectrics formed according to the present invention, however, the effective mobility reduction is much less severe while still maintaining a high nitrogen concentration and small equivalent oxide thickness.

Lastly, for the convenience of the Board, Appellants wish to note that the terms "dosage" and "concentration" are used synonymously in this Appeal Brief and in the present application. The claims as originally filed recited that the final oxynitride layer has a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Use of the term "concentration" was objected to in a prior Office Action. Specifically, the claims were rejected under both 35 U.S.C. § 112, first paragraph as lacking enablement, and 35 U.S.C. § 112, second paragraph as being indefinite, due to use of this term.

In the Amendment submitted June 20, 2003, Appellants presented a detailed explanation that use of the term "concentration" in this context would be well understood by those of ordinary skill in the art. Specifically, Appellants presented arguments detailing that it is well known in the art that nitrogen content in ultra-thin gate dielectric films is preferably expressed in atoms/cm<sup>2</sup>. Therefore the invention as originally claimed was enabled so that any person skilled in the art can make and use the invention without undue experimentation, and was also not indefinite. Nevertheless, in an effort to advance prosecution of the instant application, Appellants also amended the claims to replace the term "concentration" with the term "dosage," at the suggestion of the Examiner. Used in this context, however, it would be clear to one of ordinary skill in the art that the terms "concentration" and "dosage" are synonymous terms referring to the nitrogen content in the subject ultra-thin gate dielectric films.

### ***Issues***

The issues presented for review are as follows:

- (1) whether Claim 1 is anticipated under 35 U.S.C. § 102(b) by U.S. Patent No. 6,136,654 to Kraft et al.;
- (2) whether Claims 2-3 are unpatentable under 35 U.S.C. § 103(a) over Kraft et al.;
- (3) whether Claims 6 and 8 are unpatentable under 35 U.S.C. § 103(a) over Kraft et al. in view of U.S. Patent No. 4,980,307 to Ito et al.; and
- (4) whether Claim 7 is unpatentable under 35 U.S.C. § 103(a) over Kraft et al. in view of Gusev *et al.*, "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22.

### ***Grouping of Claims***

The rejected Claims 1-3 and 6-8 do not stand or fall together. The following groups of claims are separately patentable, for the reasons stated in the "Argument" section of this Appeal Brief:

Group A: Claims 1-3 and 6-7; and

Group B: Claim 8.

### ***Argument***

#### **Rejection of Claim 1 under 35 U.S.C. § 102(b) over Kraft et al.**

Claim 1 is rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 6,136,654 to Kraft et al. "A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference." *Verdegaal Bros. v. Union Oil Co. of California*, 814 F.2d 628, 631 (Fed. Cir. 1987). As discussed in the "Summary of Invention" section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is not disclosed by Kraft et al., as detailed below.

The Kraft et al. patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft et al. disclose that the oxygen-containing layer may be an oxide layer, an oxynitride layer, or other insulating layer (col. 3, lines 53-54).

Kraft et al., however, fail to disclose that after subjecting this oxygen-containing layer to a nitrogen-containing plasma, the layer has both an equivalent oxide thickness of less than 15 Å and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. It is alleged in the final Office Action that Kraft et al. teaches those limitations in Figure 7. Appellants respectfully disagree.

Figure 7 of the Kraft et al. patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft et al. invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of “a 35 oxide film” nitrided under specified conditions (col. 5, lines 45-48). It is apparent from this disclosure that the phrase “a 35 oxide film” was intended to mean “a 35 angstrom oxide film” for the following reasons.

First, the units of measure on the x-axis of the Figure 7 graph are “angstroms.” Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, where depth is indicated in angstroms. Moreover, in the discussion of Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen ( $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> or greater) introduced into an oxide layer by plasma nitridation causes additional growth of the layer. Thus, if a 35 Å oxide film was heavily nitrided under the conditions disclosed in the Kraft et al. patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be far greater than 35 Å. Figure 7



shows that the nitrogen concentration in the nitrided film was measured to a depth of over 50 Å. The final thickness of the film therefore must be greater than 35 Å, which supports a conclusion that the initial oxide film thickness was 35 Å. (See Declaration of Mukesh Khare, submitted October 8, 2002 and attached hereto in Appendix B, for further support of this conclusion.)

Furthermore, it is apparent from the prosecution history for the Kraft et al. patent that Figure 7 illustrates data taken from a SIMS analysis of "a 35 Å oxide film" nitrided under specified conditions. The angstrom symbol (Å) was added by Kraft et al. to the specification in the Amendment of April 28, 2000, yet the patent was issued without the requested amendment.

Figure 7 therefore clearly discloses data for an oxide film which had an initial thickness of 35 Å, and which was nitrided under conditions resulting in substantially complete formation of silicon nitride, resulting in a final thickness of over 50 Å. The equivalent oxide thickness of the final nitrided film in Figure 7 therefore can not be less than 15 Å. For this reason, Appellants therefore respectfully disagree with the statement in the Office Action that Figure 7 discloses a nitrided film having an equivalent oxide thickness of less than 15 Å.

It is further alleged in the final Office Action that since Kraft et al. disclose various ranges for the parameters to form the oxynitride, including a starting thickness of 10-150 Å for the oxide-containing layer and a nitrogen gas flow of 1-100 sccm for the plasma nitridation, "it is logical to assume that one of the many possible combinations of these parameters will result in Applicants' invention." It is unclear whether this comment is directed to the § 102(b) rejection of Claim 1, or to the § 103(a) rejections of Claims 2-3 and 6-8. If this comment is directed to the § 102(b) rejection of Claim 1, then it is presumed to be an allegation that the Kraft et al. patent inherently describes the above-identified features of Claim 1 which clearly are not expressly disclosed.

If a prior art reference does not expressly set forth a particular element of the claim, that reference still may anticipate if that element is "inherent" in its disclosure.

"To establish inherency, the extrinsic evidence 'must make clear that the missing descriptive matter is necessarily present in the thing described in the reference, and that it would be so recognized by persons of ordinary skill.'" *In re Robertson*, 169 F.3d 743, 745 (Fed. Cir. 1999) (quoting *Continental Can Co. v. Monsanto Co.*, 948 F.2d 1264, 1268 (Fed. Cir. 1991)). "Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient." *Continental Can Co.* at 1269 (quoting *In re Oelrich*, 666 F.2d 578, 581 (C.C.P.A. 1981)).

If the above-identified allegation in the final Office Action is an allegation that the Kraft et al. patent inherently describes those features of Claim 1 not expressly disclosed, then the foregoing principles were ignored. No attempt was made in the Office Action to show that the method of Kraft et al. necessarily resulted in a final oxynitride layer having both an equivalent oxide thickness of less than 15 angstroms and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, or that one skilled in the art would so recognize. No extrinsic evidence was cited to so indicate.

Instead, it is alleged that "one of the many possible combinations of [the Kraft et al.] parameters will result in Applicants' invention." This allegation is insufficient to show that the above-identified features of Claim 1 are inherent in Kraft et al. Indeed, the analysis in the final Office Action rests upon the very kind of probability or possibility that the courts have pointed out is insufficient to establish inherency.

Accordingly, Appellants respectfully submit that Kraft et al. fails to disclose, either expressly or inherently, each and every element of Claim 1, and therefore request reversal of this rejection.

#### Rejection of Claims 2-3 under 35 U.S.C. § 103(a) over Kraft et al.

Claims 2-3 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. A claimed invention is unpatentable if the differences between it and the prior art are such that the subject matter as a whole would have been obvious at the

time the invention was made to a person having ordinary skill in the art. 35 U.S.C. § 103(a). Each and every claim limitation must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981 (CCPA 1974). To establish a prima facie case of obviousness under section 103, two basic criteria must be met. First, there must be some suggestion or motivation in the prior art to modify the teaching of the reference. Second, there must be a reasonable expectation of success. *In re Vaeck*, 947 F.2d 488, 493 (Fed. Cir. 1991). Both the suggestion and the reasonable expectation of success must be founded in the prior art, not in the applicant's disclosure. *Id.* The prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Assoc., Inc. v. Garlock, Inc.*, 721 F.2d 1540 (Fed. Cir. 1983).

Claims 2 and 3 each depend from Claim 1. As discussed in the "Summary of Invention" section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al., as detailed below.

As discussed previously, the Kraft et al. patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft et al. disclose that the oxygen-containing layer is "preferably either an oxide layer, an oxynitride layer, or other insulating layer" and more preferably an oxide layer (col. 3, lines 53-56). In every embodiment of Kraft et al., an oxide layer is disclosed as the initial layer. Thus, Kraft et al. teach that an oxide layer is more preferable than an oxynitride layer as the initial layer, and therefore teach away from using an oxynitride layer as the initial layer.

Moreover, Kraft et al. fail to disclose or even suggest that the final layer, after being subjected to a nitrogen-containing plasma, has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. It is well known in the art that when an oxide-containing layer is subjected to a nitrogen-containing plasma, as taught by Kraft et al., such that the final gate dielectric has a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, the resulting gate dielectric will have an equivalent oxide thickness of greater than 15 angstroms. To achieve an equivalent oxide thickness of less than 15 angstroms, after subjecting an oxide-containing layer to a nitrogen-containing plasma using methods known in the art, the final gate dielectric will have a much lower nitrogen concentration. Prior to the present invention, an oxynitride gate dielectric having an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> had not been achieved in the art.

As discussed in the "Summary of Invention" section, Appellants have surprisingly discovered that when the initial layer is a heavily nitrated oxynitride layer, a final oxynitride layer is produced which has a substantially decreased thickness without compromising the high nitrogen concentration in the dielectric. Kraft et al. fail to recognize the superiority of using such an oxynitride layer as the initial layer, and therefore fail to suggest that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Moreover, by teaching that it is more preferred to use oxide as the initial layer rather than oxynitride, Kraft et al. are actually teaching away from achieving the above equivalent oxide thickness and nitrogen concentration in the final layer.

It is further alleged in the final Office Action that since Kraft et al. disclose various ranges for the parameters to form the oxynitride, "it is logical to assume that one of the many possible combinations of these parameters will result in Applicants' invention." It is unclear whether this comment is directed to the § 102(b) rejection of Claim 1, or to the § 103(a) rejections of Claims 2-3 and 6-8. If this comment is directed

to the § 103 rejections, then it clearly amounts to the application of a standard of “obvious-to-try,” a standard which the courts have repeatedly rejected as improper grounds for a § 103 rejection. *E.g.*, *In re Fine*, 837 F.2d 1071, 1075 (Fed. Cir. 1988); *In re Geiger*, 815 F.2d 686, 688 (Fed. Cir. 1987); *In re Merck & Co., Inc.*, 800 F.2d 1091, 1097 (Fed. Cir. 1986); *In re Antonie*, 559 F.2d 618, 620 (CCPA 1977).

“The admonition that ‘obvious to try’ is not the standard under § 103 has been directed mainly at two kinds of error. In some cases, what would have been ‘obvious to try’ would have been to vary all parameters or try each of numerous possible choices until one possibly arrived at a successful result, where the prior art gave either no indication of which parameters were critical or no direction as to which of many possible choices is likely to be successful.... In others, what was ‘obvious to try’ was to explore a new technology or general approach that seemed to be a promising field or experimentation, where the prior art gave only general guidance as to the particular form of the claimed invention or how to achieve it.” *In re O’Farrell*, 853 F.2d 894, 903 (Fed. Cir. 1988) (citations omitted). Here, the above-identified allegation falls squarely within the first of these prohibited situations.

Accordingly, Appellants respectfully submit that the Kraft et al. patent fails to disclose or even suggest each and every limitation of Claim 1. Claims 2 and 3, which include all of the limitations of Claim 1, are therefore patentable over Kraft et al. For this reason, Appellants respectfully request withdrawal of this rejection.

Rejection of Claims 6 and 8 under 35 U.S.C. § 103(a) over Kraft et al. in view of Ito et al.

Claims 6 and 8 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. in view of U.S. Patent No. 4,980,307 to Ito *et al.* Claims 6 and 8 each depend from Claim 1. As discussed in the “Summary of Invention” section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both

an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. in view of Ito et al.

As discussed previously, Kraft et al. fail to disclose or suggest, and actually teach away from, a method wherein the final layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Ito et al. fail to remedy the deficiencies of Kraft et al. in this regard.

The Ito et al. patent is directed to a process for producing an oxynitride insulative film. The insulative film is formed by nitridation of an oxide film under a nitridation atmosphere containing nitrogen atoms (col. 4, lines 46-49). In all embodiments of Ito et al., the initial layer is an oxide. Ito et al. fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, and fail to disclose or suggest a final insulative film having both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Ito et al. therefore fail to provide any motivation to modify the teaching of Kraft et al. in this regard.

Accordingly, Appellants respectfully submit that Claims 6 and 8, which include all of the limitations of Claim 1, are patentable over Kraft et al. in view of Ito et al., and therefore respectfully request withdrawal of this rejection.

Claim 8 is patentable over Kraft et al. in view of Ito et al. for the following additional reason. It is an additional feature of the invention defined by Claim 8 that the final oxynitride layer has a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer. Appellants respectfully submit that this feature is also neither disclosed nor suggested by Kraft et al. in view of Ito et al.

Kraft et al. fail to disclose or suggest anything about the effective electron mobility of their final layer with respect to their initial oxide layer. Since Kraft et al. fail to disclose or suggest that the final oxynitride layer has both an equivalent oxide thickness

of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, Kraft et al. also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer.

Ito et al. fail to remedy the deficiencies of the Kraft et al. disclosure in this regard. Since Ito et al. fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, Ito et al. therefore also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer.

For this additional reason, Appellants respectfully submit that Claim 8 is patentable over Kraft et al. in view of Ito et al., and therefore request withdrawal of this rejection.

Rejection of Claim 7 under 35 U.S.C. § 103(a) over Kraft et al. in view of Gusev et al.

Claim 7 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. in view of Gousev et al., "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22. Claim 7 depends from Claim 1. As discussed in the "Summary of Invention" section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. in view of Gousev et al.

As discussed previously, Kraft et al. fail to disclose, and actually teach away from, a method wherein the final layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Gousev et al. fail to remedy the deficiencies of Kraft et al. in this regard.

The Gousev et al. paper is directed to methods of forming and characterizing "ultrathin nitrided silicon oxide films." The title of this paper reveals that all oxynitride films discussed therein are formed by nitriding oxide films. In other words, the initial layer in all embodiments is an oxide layer. Gousev et al. fail to disclose or even suggest that the initial layer should be an oxynitride layer. Moreover, Gousev et al. fail to disclose or suggest a final oxynitride layer having an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Thus, Gousev et al. provide no motivation to modify the teaching of Kraft et al. in this regard.

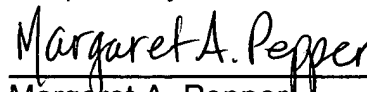
Accordingly, Appellants respectfully submit that Claim 7, which includes all of the limitations of Claim 1, is patentable over Kraft et al. in view of Gousev et al., and therefore respectfully request withdrawal of this rejection.

### **Conclusion**

For the reasons given above, Appellants submit that the instant application is in condition for allowance. Reversal of the pending rejections and passage of the application to issue are respectfully requested. Matters of a nature that may be handled by telephone or e-mail may be directed to the undersigned.

A fee of \$330.00 is believed to be due for the submission of this Appeal Brief. The Commissioner is authorized to charge this fee, and any other required fees, to Deposit Account No. 09-0458.

Respectfully submitted,



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09/809,663

FIS920000396US1



## ***Appendix A - Claims***

1. A method for forming a gate dielectric for an integrated circuit device, the method comprising:

forming an initial oxynitride layer upon a substrate material, said initial oxynitride layer having an initial thickness; and

subjecting said initial oxynitride layer to a plasma nitridation, said plasma nitridation resulting in a final oxynitride layer, said final oxynitride layer having a final thickness,

wherein said final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>.

2. The method of claim 1, wherein said final thickness exceeds said initial thickness by less than 5 angstroms.

3. The method of claim 1, wherein said final thickness is less than 20 angstroms.

6. The method of claim 1, wherein said initial oxynitride layer is formed upon said substrate by:

ionically implanting nitrogen atoms into said substrate; and

oxidizing said substrate, following said substrate being ionically implanted with nitrogen atoms.

7. The method of claim 1, wherein said initial oxynitride layer is formed upon said substrate by rapid thermal nitric oxide (NO) deposition.

8. The method of claim 6, wherein said final oxynitride layer further has a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of said initial oxynitride layer.

***Appendix B***

***Declaration of Mukesh Khare, submitted with Amendment of October 8, 2002***

I HEREBY CERTIFY THAT THIS CORRESPONDENCE IS BEING  
TRANSMITTED VIA FACSIMILE TO THE COMMISSIONER FOR  
PATENTS, WASHINGTON, D.C. 20231, ON

Date of Deposit: October 8, 2002

Name of Person Making Deposit: *Colleen Dem. Linda Gray*

Signature: *Linda Gray 10/08/02*

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE	
In Re Application of: M. Khare <i>et al.</i>	October 8, 2002
	Examiner: Fernando L. Toledo
Serial No. 09/809,663 Filing Date: March 15, 2001	Group Art Unit: 2823
Title: METHOD FOR IMPROVED PLASMA NITRIDATION OF ULTRA THIN GATE DIELECTRICS	IBM Corporation 2070 Route 52 Dept. 18G, Bldg. 300-482 Hopewell Junction, N.Y. 12533

The Commissioner for Patents  
Washington, D.C. 20231

**DECLARATION UNDER 37 C.F.R. § 1.132**

I, Mukesh Khare, declare as follows:

(1) I am one of the inventors of the subject matter disclosed and claimed in the patent application identified above.

(2) I received a Ph.D. from Yale University in 1999. The subject of my dissertation is "Advanced Gate Dielectric for ULSI Applications." I have also received the following degrees: a Master of Philosophy in Electrical Engineering (Microelectronics) from Yale University; a Master of Science in Electrical Engineering (Microelectronics) from Yale University; a Master of Technology in Electrical Engineering (Microelectronics) from the Indian Institute of Technology

in Bombay, India; and a Bachelor of Engineering in Electronics Engineering from Bombay University.

(3) I have been employed by IBM Microelectronics Division since 1998 in the Semiconductor Research and Development Center as lead integration engineer for 90 nm high performance technology. Before working at IBM, I worked at Motorola as an engineering intern in 1997 evaluating advanced processes for gate dielectric application in ultra-thin regime, and in 1996 characterizing capacitors and field effect transistors made with jet vapor deposition (JVD) nitride as gate dielectric. I also worked at Yale University Center for Microelectronic Materials and Structures on developing and investigating the properties of ultra-thin silicon nitride gate dielectric using JVD as a replacement of silicon dioxide for deep-sub-micron devices.

(4) I have published numerous technical articles relating to semiconductor applications, including: (1) Terence B. Hook, Anthony Chou, Mukesh Khare, Anda Mocuta, "A Circuit Model for Evaluating Plasma-Induced Charging Damage in Bulk and SOI Technologies," International Symposium on Plasma Process-Induced Damage, P2ID, Proceedings 2000. p 30-33; (2) Anda C. Mocuta, Terence B. Hook, Anthony I. Chou, Tina Wagner, Anthony K. Stamper, Mukesh Khare, Jeffrey P. Gambino, "Plasma charging damage in SOI Technology," 6th International Symposium on Plasma- and Process-Induced Damage, International Symposium on Plasma Process-Induced Damage, P2ID, Proceedings 2001 p.104-107; and (3) H. Park, D. Schepis, A.C. Mocuta, Mukesh Khare, Y. Li, B. Doris, S. Shukla, T. Hughes, O. Dokumaci, S. Narasimha, S. Fung, J. Snare, B.H. Lee, J. Li, P. Ronsheim, *et al.*, "Gate postdoping to decouple implant/anneal for gate, source/drain, and extension: Maximizing polysilicon gate activation for 0.1 mum CMOS technologies," 2002 Symposium on VLSI Technology Digest of Technical Papers, IEEE Symposium on VLSI Circuits, Digest of Technical Papers 2002 p.134-135.

(5) From my experience in the field of semiconductor fabrication, I am very knowledgeable about gate dielectric formation using plasma nitridation.

(6) I am familiar with the above-referenced patent application ("present application"), and its prosecution at the U.S. Patent and Trademark Office.

(7) The above-referenced patent application is directed to a method for forming a gate dielectric for an integrated circuit device. The method includes the following steps: (a) forming an initial oxynitride layer upon a substrate material, the initial oxynitride layer having an initial physical thickness; and (b) subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer having a final physical thickness. The final oxynitride layer has an equivalent oxide thickness (EOT) of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>.

(8) Claims 1-3 and 6-8 have been rejected as anticipated by or obvious over U.S. Patent No. 6,136,654 to Kraft *et al.*, either alone or in combination with other references. The basis for these rejections, as stated in the Office Action mailed August 8, 2002, is that Figure 7 of the Kraft *et al.* patent discloses a final oxynitride layer having an EOT of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. A further basis for these rejections, as stated in the Interview Summary mailed September 19, 2002, is that Figure 8 discloses an EOT of less than 15 angstroms, that the processes used to produce the Figure 7 and Figure 8 films are similar, and therefore the nitrogen concentration must also be similar.

(9) In my opinion, a person of skill in the art to which the present application is directed would understand that the Figure 7 film in the Kraft *et al.* patent does not have an EOT of less than 15 angstroms. Figure 7 of the Kraft *et al.* patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of "a 35 oxide film" nitrided under specified conditions (col. 5, lines 45-48). In my opinion, the phrase "a 35 oxide film" was intended to mean "a 35 angstrom oxide film" for the following reasons. First, Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, and the units of measure on the x-axis of this graph are "angstroms." Moreover, in the discussion of

Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen ( $2.0 \times 10^{15}/\text{cm}^2$  or greater) introduced into an oxide layer by plasma nitridation causes additional growth of the layer. Thus, if a 35 angstrom oxide film were nitrided under the conditions disclosed in the Kraft *et al.* patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be greater than 35 angstroms. Furthermore, a careful look at the SIMS plot shows that the nitrogen concentration does not go down to less than 5% until a depth of more than 35 angstroms. This plot clearly shows that the physical thickness of this film after plasma nitridation is more than 35 angstroms. Since Figure 7 shows that the nitrogen concentration in the nitrided film was measured to a depth of over 50 angstroms, the initial oxide film thickness was most likely 35 angstroms. This film with final thickness greater than 35 angstroms, even with high level of nitridation, can not have an EOT of less than 15 angstroms.

(10) It is also my opinion that a person skilled in the art would understand that the Figure 8 film in the Kraft *et al.* patent does not have an EOT of less than 15 angstroms. Figure 8 is also a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 8 illustrates data taken from a time of flight SIMS analysis of "a 7 oxide film" nitrided under specified conditions (col. 5, lines 54-56). In my opinion, the phrase "a 7 oxide film" was intended to mean "a 70 angstrom oxide film" for the following reasons. First, the units of measure for the initial thickness of the oxide film must be angstroms for the same reasons discussed above with respect to Figure 7. The units of measure on the x-axis of the Figure 8 graph are angstroms. Second, the initial thickness of the oxide film must have been 70 angstroms rather than 7 angstroms for several reasons. Kraft *et al.* disclose that the initial oxide-containing layer is preferably "a 10 to 150 [angstrom] thick" layer (col. 3, line 52). A 70 angstrom oxide film falls within this range whereas a 7 angstrom oxide film does not. More importantly, however, Figure 8 indicates that the nitrogen and oxygen concentrations in the nitrided film were measured to a depth of 90 angstroms, and that the nitrogen concentration does not begin to drop until the film thickness is about 70 angstroms. At a

thickness of about 7 angstroms, the nitrogen signal is just beginning to rise. If the final film thickness were 7 angstroms, as the Examiner alleges, then the nitrogen concentration should be zero for depths greater than 7 angstroms. In fact, Figure 8 shows the highest nitrogen concentration at 20 to 25 angstroms, and the nitrogen signal drops to a very low value after 70 angstroms. This clearly supports a conclusion that there is an error in the text of the Kraft *et al.* patent, such that the initial oxide film thickness should be 70 angstroms rather than 7 angstroms.

(11) It is my further opinion that the process conditions used by Kraft *et al.* for the Figure 8 film would not have produced a final film having an EOT of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> for the following reasons. First, it is important to note that the process of the present application begins with forming a heavily nitrided initial oxynitride layer, and concludes with subjecting this initial layer to a light nitridation in order to minimize growth of the layer. Kraft *et al.* fail to disclose any process conditions used to form an initial oxynitride layer. Indeed, Kraft *et al.* teach only that the initial layer should be an oxide-containing layer, preferably an oxide layer. Moreover, the nitridation process conditions disclosed by Kraft *et al.* indicate that their initial film is subjected to a heavy nitridation, causing significant growth of the film. The differences in process conditions are summarized in the Tables 1-3 below.

1. Formation of initial oxynitride layer by rapid thermal nitric oxide (RTNO) deposition

Process condition	IBM process	Kraft <i>et al.</i> process
Temperature	650 to 850 °C	not disclosed
Pressure	10 to 740 Torr	not disclosed
Duration	30 to 90 seconds	not disclosed



2. Formation of initial oxynitride layer by nitrogen ion implantation and rapid thermal oxidation

Process condition	IBM process	Kraft <i>et al.</i> process
Nitrogen ion implant dose	$3 \times 10^{14}$ to $8 \times 10^{14}$ atoms/cm <sup>2</sup>	not disclosed
RTO temperature	900 to 1000 °C	not disclosed
RTO time	5 to 15 seconds	not disclosed

3. Plasma nitridation of initial oxynitride layer

Process condition	IBM process (light nitridation)	Kraft <i>et al.</i> process (heavy nitridation)
Plasma power	3000 Watts	2000 Watts
Frequency	2.1 Ghz	13.56 MHz
Substrate bias	no substrate bias	450 Watts (for Fig. 8)
Nitrogen flowrate	500 to 2000 sccm	100 sccm
Helium flowrate	1000 to 5000 sccm	not disclosed
Pressure	2 to 5 Torr	4 mTorr
Duration	50-150 seconds	10 seconds (for Fig. 8)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-identified application or any patent issued thereon.

By: Mukesh V. Khare Date: 10/8/2002  
 Mukesh V. Khare



Date of Deposit: February 12, 2004

I hereby certify that this paper and fee are being deposited with the United States Postal Service as First Class Mail in an envelope addressed to Commissioner for Patents in accordance with 37 CFR Sec. 1.8(a) on the date indicated above.

Karen Cinq-Mars

Name of Person Mailing Paper and Fee

*Karen Cinq-Mars 2/12/04*  
Signature of Person Mailing Paper and Fee

## In the United States Patent and Trademark Office

**Date:** February 12, 2004

**In re Application of:** Mukesh V. Khare et al.

**Filed:** March 15, 2001

**For:** METHOD FOR IMPROVED PLASMA NITRIDATION OF  
ULTRA THIN GATE DIELECTRICS

**Serial Number:** 09/809,663

**Art Unit:** 2823

**Examiner:** Fernando L.  
Toledo

### BRIEF FOR APPELLANTS UNDER 37 C.F.R. § 1.192

#### **Mail Stop: Appeal Brief - Patents**

Hon. Commissioner of Patents and Trademarks  
P.O. Box 1450  
Alexandria, VA 22313-1450

Sir:

This is an appeal from the final Office Action mailed September 17, 2003, rejecting Claims 1-3 and 6-8. A Notice of Appeal and the required fee were timely filed on December 17, 2003. Three copies of this Appeal Brief are enclosed.

09/809,663

FIS920000396US1

***Real Party in Interest***

The real party in interest is the assignee of the entire right, title and interest in this application, International Business Machines Corporation, a corporation of the State of New York, having a place of business at Armonk, New York 10504.

***Related Appeals and Interferences***

There are no appeals or interferences known to Appellants, Appellants' legal representatives, or assignee, which will directly affect or be affected by or have a bearing on the Board's decision in the pending appeal.

***Status of Claims***

The subject application was filed on March 15, 2001 with Claims 1-13. In a first Office Action mailed February 28, 2002, Claims 9-13 were withdrawn from consideration and Claims 1-8 were rejected. An Amendment was filed on May 28, 2002, canceling Claims 4, 5 and 9-13 and amending Claims 1-3. A second Office Action mailed August 8, 2002 was made final, and the prior art rejections of Claims 1-3 and 6-8 were maintained. A response was filed on October 8, 2002, presenting arguments and a declaration under 37 C.F.R. 1.132. In a third Office Action mailed November 11, 2002, the finality of the previous Office Action was withdrawn, the prior art rejections of Claims 1-3 and 6-8 were also withdrawn, and these claims were rejected only under the nonstatutory doctrine of obviousness-type double patenting. A response was filed on December 30, 2002, which included a terminal disclaimer to overcome the double patenting rejection.

Instead of a Notice of Allowance, a fourth Office Action was mailed March 20, 2003, essentially repeating the same rejections which appeared in the second Office Action mailed August 8, 2002. In an Amendment filed June 20, 2003, arguments were re-presented, again referring to the declaration under 37 C.F.R. 1.132, and Claim

1 was amended. A final Office Action followed on September 17, 2003, maintaining the rejection of Claims 1-3 and 6-8. Appellants are appealing the rejection of these claims.

Appellants also wish to note that a Supplemental Information Disclosure Statement (IDS) was filed on July 8, 2003. This Supplemental IDS was filed before the mailing date of the final Office Action and was accompanied by a statement that each item of information contained in the IDS was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the IDS. Even though the requirements of 37 C.F.R. 1.97(c) have been satisfied, receipt of this Supplemental IDS has not been acknowledged, and this Supplemental IDS has not been made of record in the application.

#### ***Status of Amendments***

All the amendments made during prosecution of the application have been entered. The rejected Claims 1-3 and 6-8, as they presently stand, are set forth in Appendix A. No amendment has been filed subsequent to the final rejection.

#### ***Summary of Invention***

The present invention is directed to a method for improved plasma nitridation of ultra thin gate dielectrics in integrated circuits. Specifically, this method addresses the need for a method which results in a higher nitrogen concentration or dosage in the dielectric, yet does not substantially increase the dielectric thickness or sacrifice the uniformity of film thickness.

Prior to the present invention, it was known that nitrogen doping of silicon oxide dielectric material, particularly by Remote Plasma Nitridation (RPN), increases the dielectric constant of the material. An increased dielectric constant in gate dielectrics is desirable to help reduce the amount of leakage current experienced as compared to an undoped silicon oxide layer having the same capacitance.

Conventional methods of plasma nitridation, however, have several drawbacks when used in conjunction with gate thicknesses of around 15 Å or less. First, a relatively strong concentration of nitrogen ( $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> or greater) introduced into an oxide layer by RPN, while desirable for the purpose of reducing leakage current, causes an additional growth of the layer. In ULSI integrated circuits, it is desired to maintain the physical thickness of gate dielectrics to around 15 Å. An oxide gate dielectric layer having an initial physical thickness of approximately 15 Å, when subjected to RPN, will grow in physical thickness by as much as 10-15 Å. This additional growth caused by conventional plasma nitridation is therefore highly undesirable in ULSI integrated circuits. Secondly, the direct nitridation of a silicon oxide layer typically results in a non-uniform distribution of nitrogen atoms within the layer. As a result, the uneven growth of film at the interface during nitridation affects the overall uniformity of the film thickness.

These deficiencies of the prior art are overcome by the method of the present invention. The method comprises the steps of: forming an initial oxynitride layer upon a substrate material, and subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer. It is a feature of the present invention that the final oxynitride layer has both an equivalent oxide thickness of less than 15 Å and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. The equivalent oxide thickness is a relative measure of gate dielectric thickness with respect to the actual thickness of a silicon oxide layer having the same capacitance value as the given gate dielectric. Applicants have surprisingly discovered that when the initial layer is a heavily nitrated oxynitride layer instead of a silicon oxide layer, a final oxynitride layer is produced which has a substantially decreased thickness without compromising the high nitrogen concentration in the dielectric.

It is an additional feature of the present invention that the final oxynitride layer further has a reduction in effective electron mobility of less than 20% from the effective electron mobility of the initial oxynitride layer. Electron mobility relates to the

speed of the device. A conventional method involving plasma nitridation of a silicon oxide film can cause the effective electron mobility of the gate dielectric to be reduced by as much as 50-70 %. In gate dielectrics formed according to the present invention, however, the effective mobility reduction is much less severe while still maintaining a high nitrogen concentration and small equivalent oxide thickness.

Lastly, for the convenience of the Board, Appellants wish to note that the terms "dosage" and "concentration" are used synonymously in this Appeal Brief and in the present application. The claims as originally filed recited that the final oxynitride layer has a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Use of the term "concentration" was objected to in a prior Office Action. Specifically, the claims were rejected under both 35 U.S.C. § 112, first paragraph as lacking enablement, and 35 U.S.C. § 112, second paragraph as being indefinite, due to use of this term.

In the Amendment submitted June 20, 2003, Appellants presented a detailed explanation that use of the term "concentration" in this context would be well understood by those of ordinary skill in the art. Specifically, Appellants presented arguments detailing that it is well known in the art that nitrogen content in ultra-thin gate dielectric films is preferably expressed in atoms/cm<sup>2</sup>. Therefore the invention as originally claimed was enabled so that any person skilled in the art can make and use the invention without undue experimentation, and was also not indefinite. Nevertheless, in an effort to advance prosecution of the instant application, Appellants also amended the claims to replace the term "concentration" with the term "dosage," at the suggestion of the Examiner. Used in this context, however, it would be clear to one of ordinary skill in the art that the terms "concentration" and "dosage" are synonymous terms referring to the nitrogen content in the subject ultra-thin gate dielectric films.

### ***Issues***

The issues presented for review are as follows:

- (1) whether Claim 1 is anticipated under 35 U.S.C. § 102(b) by U.S. Patent No. 6,136,654 to Kraft et al.;
- (2) whether Claims 2-3 are unpatentable under 35 U.S.C. § 103(a) over Kraft et al.;
- (3) whether Claims 6 and 8 are unpatentable under 35 U.S.C. § 103(a) over Kraft et al. in view of U.S. Patent No. 4,980,307 to Ito et al.; and
- (4) whether Claim 7 is unpatentable under 35 U.S.C. § 103(a) over Kraft et al. in view of Gusev *et al.*, "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22.

### ***Grouping of Claims***

The rejected Claims 1-3 and 6-8 do not stand or fall together. The following groups of claims are separately patentable, for the reasons stated in the "Argument" section of this Appeal Brief:

Group A: Claims 1-3 and 6-7; and

Group B: Claim 8.

### ***Argument***

#### **Rejection of Claim 1 under 35 U.S.C. § 102(b) over Kraft et al.**

Claim 1 is rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 6,136,654 to Kraft et al. "A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference." *Verdegaal Bros. v. Union Oil Co. of California*, 814 F.2d 628, 631 (Fed. Cir. 1987). As discussed in the "Summary of Invention" section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is not disclosed by Kraft et al., as detailed below.

The Kraft et al. patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft et al. disclose that the oxygen-containing layer may be an oxide layer, an oxynitride layer, or other insulating layer (col. 3, lines 53-54).

Kraft et al., however, fail to disclose that after subjecting this oxygen-containing layer to a nitrogen-containing plasma, the layer has both an equivalent oxide thickness of less than 15 Å and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. It is alleged in the final Office Action that Kraft et al. teaches those limitations in Figure 7. Appellants respectfully disagree.

Figure 7 of the Kraft et al. patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft et al. invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of "a 35 oxide film" nitrided under specified conditions (col. 5, lines 45-48). It is apparent from this disclosure that the phrase "a 35 oxide film" was intended to mean "a 35 angstrom oxide film" for the following reasons.

First, the units of measure on the x-axis of the Figure 7 graph are "angstroms." Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, where depth is indicated in angstroms. Moreover, in the discussion of Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen ( $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> or greater) introduced into an oxide layer by plasma nitridation causes additional growth of the layer. Thus, if a 35 Å oxide film was heavily nitrided under the conditions disclosed in the Kraft et al. patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be far greater than 35 Å. Figure 7



shows that the nitrogen concentration in the nitrided film was measured to a depth of over 50 Å. The final thickness of the film therefore must be greater than 35 Å, which supports a conclusion that the initial oxide film thickness was 35 Å. (See Declaration of Mukesh Khare, submitted October 8, 2002 and attached hereto in Appendix B, for further support of this conclusion.)

Furthermore, it is apparent from the prosecution history for the Kraft et al. patent that Figure 7 illustrates data taken from a SIMS analysis of "a 35 Å oxide film" nitrided under specified conditions. The angstrom symbol (Å) was added by Kraft et al. to the specification in the Amendment of April 28, 2000, yet the patent was issued without the requested amendment.

Figure 7 therefore clearly discloses data for an oxide film which had an initial thickness of 35 Å, and which was nitrided under conditions resulting in substantially complete formation of silicon nitride, resulting in a final thickness of over 50 Å. The equivalent oxide thickness of the final nitrided film in Figure 7 therefore can not be less than 15 Å. For this reason, Appellants therefore respectfully disagree with the statement in the Office Action that Figure 7 discloses a nitrided film having an equivalent oxide thickness of less than 15 Å.

It is further alleged in the final Office Action that since Kraft et al. disclose various ranges for the parameters to form the oxynitride, including a starting thickness of 10-150 Å for the oxide-containing layer and a nitrogen gas flow of 1-100 sccm for the plasma nitridation, "it is logical to assume that one of the many possible combinations of these parameters will result in Applicants' invention." It is unclear whether this comment is directed to the § 102(b) rejection of Claim 1, or to the § 103(a) rejections of Claims 2-3 and 6-8. If this comment is directed to the § 102(b) rejection of Claim 1, then it is presumed to be an allegation that the Kraft et al. patent inherently describes the above-identified features of Claim 1 which clearly are not expressly disclosed.

If a prior art reference does not expressly set forth a particular element of the claim, that reference still may anticipate if that element is "inherent" in its disclosure.

“To establish inherency, the extrinsic evidence ‘must make clear that the missing descriptive matter is necessarily present in the thing described in the reference, and that it would be so recognized by persons of ordinary skill.’” *In re Robertson*, 169 F.3d 743, 745 (Fed. Cir. 1999) (quoting *Continental Can Co. v. Monsanto Co.*, 948 F.2d 1264, 1268 (Fed. Cir. 1991)). “Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient.” *Continental Can Co.* at 1269 (quoting *In re Oelrich*, 666 F.2d 578, 581 (C.C.P.A. 1981)).

If the above-identified allegation in the final Office Action is an allegation that the Kraft et al. patent inherently describes those features of Claim 1 not expressly disclosed, then the foregoing principles were ignored. No attempt was made in the Office Action to show that the method of Kraft et al. necessarily resulted in a final oxynitride layer having both an equivalent oxide thickness of less than 15 angstroms and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, or that one skilled in the art would so recognize. No extrinsic evidence was cited to so indicate.

Instead, it is alleged that “one of the many possible combinations of [the Kraft et al.] parameters will result in Applicants’ invention.” This allegation is insufficient to show that the above-identified features of Claim 1 are inherent in Kraft et al. Indeed, the analysis in the final Office Action rests upon the very kind of probability or possibility that the courts have pointed out is insufficient to establish inherency.

Accordingly, Appellants respectfully submit that Kraft et al. fails to disclose, either expressly or inherently, each and every element of Claim 1, and therefore request reversal of this rejection.

#### Rejection of Claims 2-3 under 35 U.S.C. § 103(a) over Kraft et al.

Claims 2-3 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. A claimed invention is unpatentable if the differences between it and the prior art are such that the subject matter as a whole would have been obvious at the

time the invention was made to a person having ordinary skill in the art. 35 U.S.C. § 103(a). Each and every claim limitation must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981 (CCPA 1974). To establish a prima facie case of obviousness under section 103, two basic criteria must be met. First, there must be some suggestion or motivation in the prior art to modify the teaching of the reference. Second, there must be a reasonable expectation of success. *In re Vaeck*, 947 F.2d 488, 493 (Fed. Cir. 1991). Both the suggestion and the reasonable expectation of success must be founded in the prior art, not in the applicant's disclosure. *Id.* The prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Assoc., Inc. v. Garlock, Inc.*, 721 F.2d 1540 (Fed. Cir. 1983).

Claims 2 and 3 each depend from Claim 1. As discussed in the "Summary of Invention" section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al., as detailed below.

As discussed previously, the Kraft et al. patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft et al. disclose that the oxygen-containing layer is "preferably either an oxide layer, an oxynitride layer, or other insulating layer" and more preferably an oxide layer (col. 3, lines 53-56). In every embodiment of Kraft et al., an oxide layer is disclosed as the initial layer. Thus, Kraft et al. teach that an oxide layer is more preferable than an oxynitride layer as the initial layer, and therefore teach away from using an oxynitride layer as the initial layer.

Moreover, Kraft et al. fail to disclose or even suggest that the final layer, after being subjected to a nitrogen-containing plasma, has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. It is well known in the art that when an oxide-containing layer is subjected to a nitrogen-containing plasma, as taught by Kraft et al., such that the final gate dielectric has a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, the resulting gate dielectric will have an equivalent oxide thickness of greater than 15 angstroms. To achieve an equivalent oxide thickness of less than 15 angstroms, after subjecting an oxide-containing layer to a nitrogen-containing plasma using methods known in the art, the final gate dielectric will have a much lower nitrogen concentration. Prior to the present invention, an oxynitride gate dielectric having an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> had not been achieved in the art.

As discussed in the "Summary of Invention" section, Appellants have surprisingly discovered that when the initial layer is a heavily nitrated oxynitride layer, a final oxynitride layer is produced which has a substantially decreased thickness without compromising the high nitrogen concentration in the dielectric. Kraft et al. fail to recognize the superiority of using such an oxynitride layer as the initial layer, and therefore fail to suggest that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Moreover, by teaching that it is more preferred to use oxide as the initial layer rather than oxynitride, Kraft et al. are actually teaching away from achieving the above equivalent oxide thickness and nitrogen concentration in the final layer.

It is further alleged in the final Office Action that since Kraft et al. disclose various ranges for the parameters to form the oxynitride, "it is logical to assume that one of the many possible combinations of these parameters will result in Applicants' invention." It is unclear whether this comment is directed to the § 102(b) rejection of Claim 1, or to the § 103(a) rejections of Claims 2-3 and 6-8. If this comment is directed

to the § 103 rejections, then it clearly amounts to the application of a standard of “obvious-to-try,” a standard which the courts have repeatedly rejected as improper grounds for a § 103 rejection. *E.g.*, *In re Fine*, 837 F.2d 1071, 1075 (Fed. Cir. 1988); *In re Geiger*, 815 F.2d 686, 688 (Fed. Cir. 1987); *In re Merck & Co., Inc.*, 800 F.2d 1091, 1097 (Fed. Cir. 1986); *In re Antonie*, 559 F.2d 618, 620 (CCPA 1977).

“The admonition that ‘obvious to try’ is not the standard under § 103 has been directed mainly at two kinds of error. In some cases, what would have been ‘obvious to try’ would have been to vary all parameters or try each of numerous possible choices until one possibly arrived at a successful result, where the prior art gave either no indication of which parameters were critical or no direction as to which of many possible choices is likely to be successful.... In others, what was ‘obvious to try’ was to explore a new technology or general approach that seemed to be a promising field or experimentation, where the prior art gave only general guidance as to the particular form of the claimed invention or how to achieve it.” *In re O’Farrell*, 853 F.2d 894, 903 (Fed. Cir. 1988) (citations omitted). Here, the above-identified allegation falls squarely within the first of these prohibited situations.

Accordingly, Appellants respectfully submit that the Kraft et al. patent fails to disclose or even suggest each and every limitation of Claim 1. Claims 2 and 3, which include all of the limitations of Claim 1, are therefore patentable over Kraft et al. For this reason, Appellants respectfully request withdrawal of this rejection.

Rejection of Claims 6 and 8 under 35 U.S.C. § 103(a) over Kraft et al. in view of Ito et al.

Claims 6 and 8 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. in view of U.S. Patent No. 4,980,307 to Ito *et al.* Claims 6 and 8 each depend from Claim 1. As discussed in the “Summary of Invention” section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both

an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. in view of Ito et al.

As discussed previously, Kraft et al. fail to disclose or suggest, and actually teach away from, a method wherein the final layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Ito et al. fail to remedy the deficiencies of Kraft et al. in this regard.

The Ito et al. patent is directed to a process for producing an oxynitride insulative film. The insulative film is formed by nitridation of an oxide film under a nitridation atmosphere containing nitrogen atoms (col. 4, lines 46-49). In all embodiments of Ito et al., the initial layer is an oxide. Ito et al. fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, and fail to disclose or suggest a final insulative film having both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Ito et al. therefore fail to provide any motivation to modify the teaching of Kraft et al. in this regard.

Accordingly, Appellants respectfully submit that Claims 6 and 8, which include all of the limitations of Claim 1, are patentable over Kraft et al. in view of Ito et al., and therefore respectfully request withdrawal of this rejection.

Claim 8 is patentable over Kraft et al. in view of Ito et al. for the following additional reason. It is an additional feature of the invention defined by Claim 8 that the final oxynitride layer has a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer. Appellants respectfully submit that this feature is also neither disclosed nor suggested by Kraft et al. in view of Ito et al.

Kraft et al. fail to disclose or suggest anything about the effective electron mobility of their final layer with respect to their initial oxide layer. Since Kraft et al. fail to disclose or suggest that the final oxynitride layer has both an equivalent oxide thickness

of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, Kraft et al. also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer.

Ito et al. fail to remedy the deficiencies of the Kraft et al. disclosure in this regard. Since Ito et al. fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, Ito et al. therefore also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer.

For this additional reason, Appellants respectfully submit that Claim 8 is patentable over Kraft et al. in view of Ito et al., and therefore request withdrawal of this rejection.

Rejection of Claim 7 under 35 U.S.C. § 103(a) over Kraft et al. in view of Gusev et al.

Claim 7 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft et al. in view of Gousev et al., "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22. Claim 7 depends from Claim 1. As discussed in the "Summary of Invention" section, it is a feature of the invention defined by Claim 1 that the final oxynitride layer has both an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Appellants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. in view of Gousev et al.

As discussed previously, Kraft et al. fail to disclose, and actually teach away from, a method wherein the final layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Gousev et al. fail to remedy the deficiencies of Kraft et al. in this regard.

The Gousev et al. paper is directed to methods of forming and characterizing "ultrathin nitrided silicon oxide films." The title of this paper reveals that all oxynitride films discussed therein are formed by nitriding oxide films. In other words, the initial layer in all embodiments is an oxide layer. Gousev et al. fail to disclose or even suggest that the initial layer should be an oxynitride layer. Moreover, Gousev et al. fail to disclose or suggest a final oxynitride layer having an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Thus, Gousev et al. provide no motivation to modify the teaching of Kraft et al. in this regard.

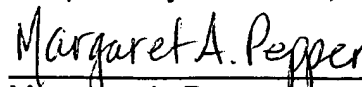
Accordingly, Appellants respectfully submit that Claim 7, which includes all of the limitations of Claim 1, is patentable over Kraft et al. in view of Gousev et al., and therefore respectfully request withdrawal of this rejection.

### ***Conclusion***

For the reasons given above, Appellants submit that the instant application is in condition for allowance. Reversal of the pending rejections and passage of the application to issue are respectfully requested. Matters of a nature that may be handled by telephone or e-mail may be directed to the undersigned.

A fee of \$330.00 is believed to be due for the submission of this Appeal Brief. The Commissioner is authorized to charge this fee, and any other required fees, to Deposit Account No. 09-0458.

Respectfully submitted,



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09/809,663

FIS920000396US1



## ***Appendix A - Claims***

1. A method for forming a gate dielectric for an integrated circuit device, the method comprising:

forming an initial oxynitride layer upon a substrate material, said initial oxynitride layer having an initial thickness; and

subjecting said initial oxynitride layer to a plasma nitridation, said plasma nitridation resulting in a final oxynitride layer, said final oxynitride layer having a final thickness,

wherein said final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen dosage of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>.

2. The method of claim 1, wherein said final thickness exceeds said initial thickness by less than 5 angstroms.

3. The method of claim 1, wherein said final thickness is less than 20 angstroms.

6. The method of claim 1, wherein said initial oxynitride layer is formed upon said substrate by:

ionically implanting nitrogen atoms into said substrate; and

oxidizing said substrate, following said substrate being ionically implanted with nitrogen atoms.

7. The method of claim 1, wherein said initial oxynitride layer is formed upon said substrate by rapid thermal nitric oxide (NO) deposition.

8. The method of claim 6, wherein said final oxynitride layer further has a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of said initial oxynitride layer.

## ***Appendix B***

***Declaration of Mukesh Khare, submitted with Amendment of October 8, 2002***

I HEREBY CERTIFY THAT THIS CORRESPONDENCE IS BEING  
TRANSMITTED VIA FACSIMILE TO THE COMMISSIONER FOR  
PATENTS, WASHINGTON, D.C. 20231, ON

Date of Deposit: October 8, 2002

Name of Person Making Deposit: Colleen Dem. Linda Gray

Signature: Linda Gray 10/08/02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE	
In Re Application of: M. Khare <i>et al.</i>	October 8, 2002
	Examiner: Fernando L. Toledo
Serial No. 09/809,663 Filing Date: March 15, 2001	Group Art Unit: 2823
Title: METHOD FOR IMPROVED PLASMA NITRIDATION OF ULTRA THIN GATE DIELECTRICS	IBM Corporation 2070 Route 52 Dept. 18G, Bldg. 300-482 Hopewell Junction, N.Y. 12533

The Commissioner for Patents  
Washington, D.C. 20231

**DECLARATION UNDER 37 C.F.R. § 1.132**

I, Mukesh Khare, declare as follows:

(1) I am one of the inventors of the subject matter disclosed and claimed in the patent application identified above.

(2) I received a Ph.D. from Yale University in 1999. The subject of my dissertation is "Advanced Gate Dielectric for ULSI Applications." I have also received the following degrees: a Master of Philosophy in Electrical Engineering (Microelectronics) from Yale University; a Master of Science in Electrical Engineering (Microelectronics) from Yale University; a Master of Technology in Electrical Engineering (Microelectronics) from the Indian Institute of Technology

in Bombay, India; and a Bachelor of Engineering in Electronics Engineering from Bombay University.

(3) I have been employed by IBM Microelectronics Division since 1998 in the Semiconductor Research and Development Center as lead integration engineer for 90 nm high performance technology. Before working at IBM, I worked at Motorola as an engineering intern in 1997 evaluating advanced processes for gate dielectric application in ultra-thin regime, and in 1996 characterizing capacitors and field effect transistors made with jet vapor deposition (JVD) nitride as gate dielectric. I also worked at Yale University Center for Microelectronic Materials and Structures on developing and investigating the properties of ultra-thin silicon nitride gate dielectric using JVD as a replacement of silicon dioxide for deep-sub-micron devices.

(4) I have published numerous technical articles relating to semiconductor applications, including: (1) Terence B. Hook, Anthony Chou, Mukesh Khare, Anda Mocuta, "A Circuit Model for Evaluating Plasma-Induced Charging Damage in Bulk and SOI Technologies," International Symposium on Plasma Process-Induced Damage, P2ID, Proceedings 2000. p 30-33; (2) Anda C. Mocuta, Terence B. Hook, Anthony I. Chou, Tina Wagner, Anthony K. Stamper, Mukesh Khare, Jeffrey P. Gambino, "Plasma charging damage in SOI Technology," 6th International Symposium on Plasma- and Process-Induced Damage, International Symposium on Plasma Process-Induced Damage, P2ID, Proceedings 2001 p.104-107; and (3) H. Park, D. Schepis, A.C. Mocuta, Mukesh Khare, Y. Li, B. Doris, S. Shukla, T. Hughes, O. Dokumaci, S. Narasimha, S. Fung, J. Snare, B.H. Lee, J. Li, P. Ronsheim, *et al.*, "Gate postdoping to decouple implant/anneal for gate, source/drain, and extension: Maximizing polysilicon gate activation for 0.1  $\mu\text{m}$  CMOS technologies," 2002 Symposium on VLSI Technology Digest of Technical Papers, IEEE Symposium on VLSI Circuits, Digest of Technical Papers 2002 p.134-135.

(5) From my experience in the field of semiconductor fabrication, I am very knowledgeable about gate dielectric formation using plasma nitridation.

(6) I am familiar with the above-referenced patent application ("present application"), and its prosecution at the U.S. Patent and Trademark Office.

(7) The above-referenced patent application is directed to a method for forming a gate dielectric for an integrated circuit device. The method includes the following steps: (a) forming an initial oxynitride layer upon a substrate material, the initial oxynitride layer having an initial physical thickness; and (b) subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer having a final physical thickness. The final oxynitride layer has an equivalent oxide thickness (EOT) of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>.

(8) Claims 1-3 and 6-8 have been rejected as anticipated by or obvious over U.S. Patent No. 6,136,654 to Kraft *et al.*, either alone or in combination with other references. The basis for these rejections, as stated in the Office Action mailed August 8, 2002, is that Figure 7 of the Kraft *et al.* patent discloses a final oxynitride layer having an EOT of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. A further basis for these rejections, as stated in the Interview Summary mailed September 19, 2002, is that Figure 8 discloses an EOT of less than 15 angstroms, that the processes used to produce the Figure 7 and Figure 8 films are similar, and therefore the nitrogen concentration must also be similar.

(9) In my opinion, a person of skill in the art to which the present application is directed would understand that the Figure 7 film in the Kraft *et al.* patent does not have an EOT of less than 15 angstroms. Figure 7 of the Kraft *et al.* patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of "a 35 oxide film" nitrided under specified conditions (col. 5, lines 45-48). In my opinion, the phrase "a 35 oxide film" was intended to mean "a 35 angstrom oxide film" for the following reasons. First, Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, and the units of measure on the x-axis of this graph are "angstroms." Moreover, in the discussion of

Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen ( $2.0 \times 10^{15}/\text{cm}^2$  or greater) introduced into an oxide layer by plasma nitridation causes additional growth of the layer. Thus, if a 35 angstrom oxide film were nitrided under the conditions disclosed in the Kraft *et al.* patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be greater than 35 angstroms.

Furthermore, a careful look at the SIMS plot shows that the nitrogen concentration does not go down to less than 5% until a depth of more than 35 angstroms. This plot clearly shows that the physical thickness of this film after plasma nitridation is more than 35 angstroms. Since Figure 7 shows that the nitrogen concentration in the nitrided film was measured to a depth of over 50 angstroms, the initial oxide film thickness was most likely 35 angstroms. This film with final thickness greater than 35 angstroms, even with high level of nitridation, can not have an EOT of less than 15 angstroms.

(10) It is also my opinion that a person skilled in the art would understand that the Figure 8 film in the Kraft *et al.* patent does not have an EOT of less than 15 angstroms. Figure 8 is also a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 8 illustrates data taken from a time of flight SIMS analysis of "a 7 oxide film" nitrided under specified conditions (col. 5, lines 54-56). In my opinion, the phrase "a 7 oxide film" was intended to mean "a 70 angstrom oxide film" for the following reasons. First, the units of measure for the initial thickness of the oxide film must be angstroms for the same reasons discussed above with respect to Figure 7. The units of measure on the x-axis of the Figure 8 graph are angstroms. Second, the initial thickness of the oxide film must have been 70 angstroms rather than 7 angstroms for several reasons. Kraft *et al.* disclose that the initial oxide-containing layer is preferably "a 10 to 150 [angstrom] thick" layer (col. 3, line 52). A 70 angstrom oxide film falls within this range whereas a 7 angstrom oxide film does not. More importantly, however, Figure 8 indicates that the nitrogen and oxygen concentrations in the nitrided film were measured to a depth of 90 angstroms, and that the nitrogen concentration does not begin to drop until the film thickness is about 70 angstroms. At a

thickness of about 7 angstroms, the nitrogen signal is just beginning to rise. If the final film thickness were 7 angstroms, as the Examiner alleges, then the nitrogen concentration should be zero for depths greater than 7 angstroms. In fact, Figure 8 shows the highest nitrogen concentration at 20 to 25 angstroms, and the nitrogen signal drops to a very low value after 70 angstroms. This clearly supports a conclusion that there is an error in the text of the Kraft *et al.* patent, such that the initial oxide film thickness should be 70 angstroms rather than 7 angstroms.

(11) It is my further opinion that the process conditions used by Kraft *et al.* for the Figure 8 film would not have produced a final film having an EOT of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> for the following reasons. First, it is important to note that the process of the present application begins with forming a heavily nitrated initial oxynitride layer, and concludes with subjecting this initial layer to a light nitridation in order to minimize growth of the layer. Kraft *et al.* fail to disclose any process conditions used to form an initial oxynitride layer. Indeed, Kraft *et al.* teach only that the initial layer should be an oxide-containing layer, preferably an oxide layer. Moreover, the nitridation process conditions disclosed by Kraft *et al.* indicate that their initial film is subjected to a heavy nitridation, causing significant growth of the film. The differences in process conditions are summarized in the Tables 1-3 below.

1. Formation of initial oxynitride layer by rapid thermal nitric oxide (RTNO) deposition

Process condition	IBM process	Kraft <i>et al.</i> process
Temperature	650 to 850 °C	not disclosed
Pressure	10 to 740 Torr	not disclosed
Duration	30 to 90 seconds	not disclosed



2. Formation of initial oxynitride layer by nitrogen ion implantation and rapid thermal oxidation

Process condition	IBM process	Kraft <i>et al.</i> process
Nitrogen ion implant dose	$3 \times 10^{14}$ to $8 \times 10^{14}$ atoms/cm <sup>2</sup>	not disclosed
RTO temperature	900 to 1000 °C	not disclosed
RTO time	5 to 15 seconds	not disclosed

3. Plasma nitridation of initial oxynitride layer

Process condition	IBM process (light nitridation)	Kraft <i>et al.</i> process (heavy nitridation)
Plasma power	3000 Watts	2000 Watts
Frequency	2.1 Ghz	13.56 MHz
Substrate bias	no substrate bias	450 Watts (for Fig. 8)
Nitrogen flowrate	500 to 2000 sccm	100 sccm
Helium flowrate	1000 to 5000 sccm	not disclosed
Pressure	2 to 5 Torr	4 mTorr
Duration	50-150 seconds	10 seconds (for Fig. 8)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-identified application or any patent issued thereon.

By: Mukesh V. Khare  
 Mukesh V. Khare

Date: 10/8/2002